Defects in Crystalline Solids (Part-I)
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Lecture – 26
Resistance to Dislocation Motion + Peierl Nebarro Valley

So, we said that we will talk about motion of the Dislocations and we have, earlier also mention there. There are two basically different types of motion. One is glide, which is also called conservative and the other is climb.

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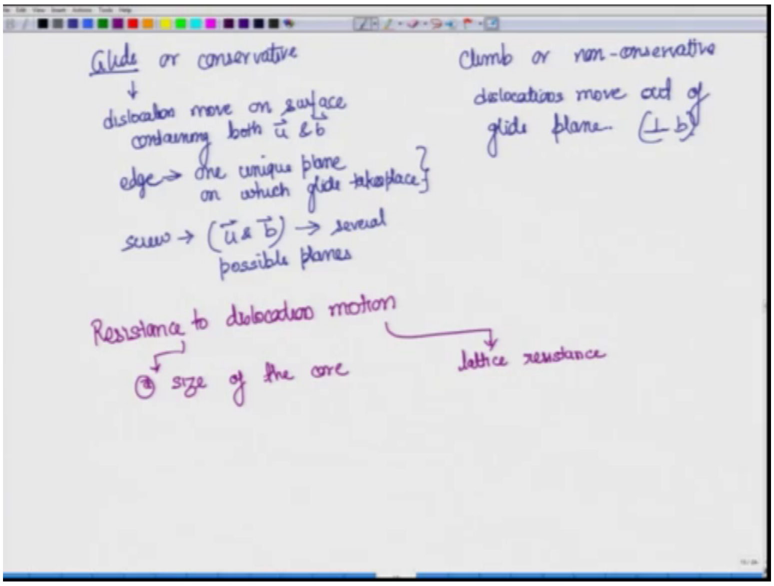

So, in this particular one the, dislocations move on surface containing both, line vector. Let me write it as line vector and burger vector. In this particular case dislocations, move out of the glide plane. So, this is perpendicular to b.

Now, when we talk about glide for edge, it will have different meaning; for screw, it will have different meaning. For edge dislocation it would mean that there is one unique plane will come back to this concept again. So, there is only one unique plane, because u and b they are perpendicular to each other which means that the plane containing this would be unique.

So, unique one, unique plane on which glide takes place. For its screw at a particular time, it will be moving on one particular plane, but it can also change to other why, because here u and b are in the same direction. Therefore, there is no unique plane which contains u and b. So, there are several possible planes, onto which screw dislocation can move only that it has to satisfy certain criterions which will see later on.

So, there is different meaning of glide, but for edge dislocation as we can see there is only one plane and this helps us this will, help us understand the concept of lattice movement. Now, were that we are talking about one unique plane.

So, let us see what exactly does it mean by movement and where does this resistance comes from. Since it is talking about one unique plane, we will be able to explain it better in these terms. The same concept can then will be extended to the screw dislocation. So, let us see what exactly we mean by Resistance to Dislocation Movement.

So, the resistance; so, we will be talking first with respect to glide and glide of edge dislocation. So, resistance to dislocation movement motion can be associated with two different aspects. One is related to size of the core and other is related to what we can call as lattice resistance.

So, size of the core so far we thought that there is, particular size of the core we had defined it, but that is those were just simplification. In reality when you look at the structure the core size can be understood in terms of how much strain it is experiencing.

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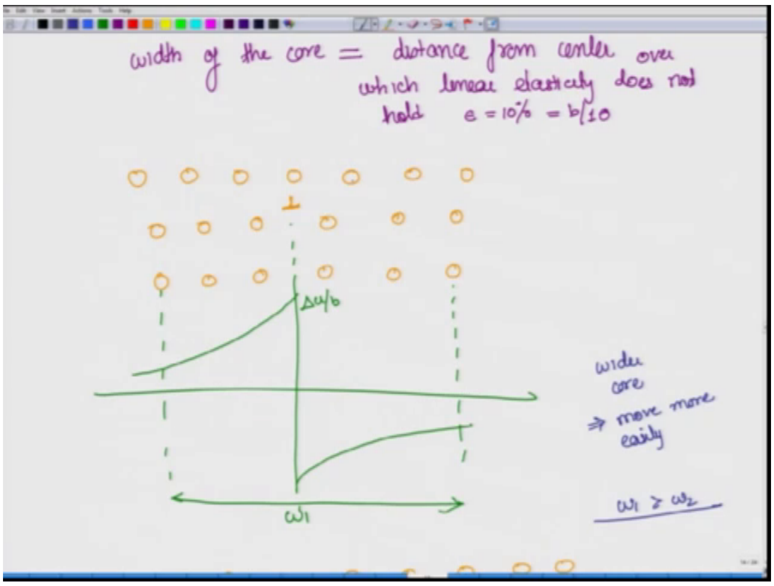

So, for example, there is something called as width of the core what is width of the core it is defined as distance from centre. The centre of the dislocation, over which this is our older definition or which linear elasticity does not hold and we had earlier said that this is approximately equal to 10 percent or equal to b by 10.

So, if our b is the burger vector with respect to whose which we are calculating the strain. So, the 10 percent of this will be b by 10. What does it mean physically? So, does student this imply that everything will have the same core radius no, we will see here.Let us say again, we said that edge dislocation would be easier to understand, which is why you will see here. So, you see where is the dislocation? The dislocation is over here, right and if you look at the strain just below the plane, then the strain can be depicted like this.

Let us talk, in terms of displacement. So, displacement with respect to b which is the strain value and as you can see this strain is contouring all the way up to this point. So, let us say this is somewhere over here, where you are getting 10 percent value. So, this is like this.

So, up to this much distance is your core. On the other hand, I will have to, I would like to draw it over here. So, that the comparison is, easier to make. So, let me draw it over here. So, here also will draw the same dislocation, but what you will see is that the strain is limited in a much smaller diameter.

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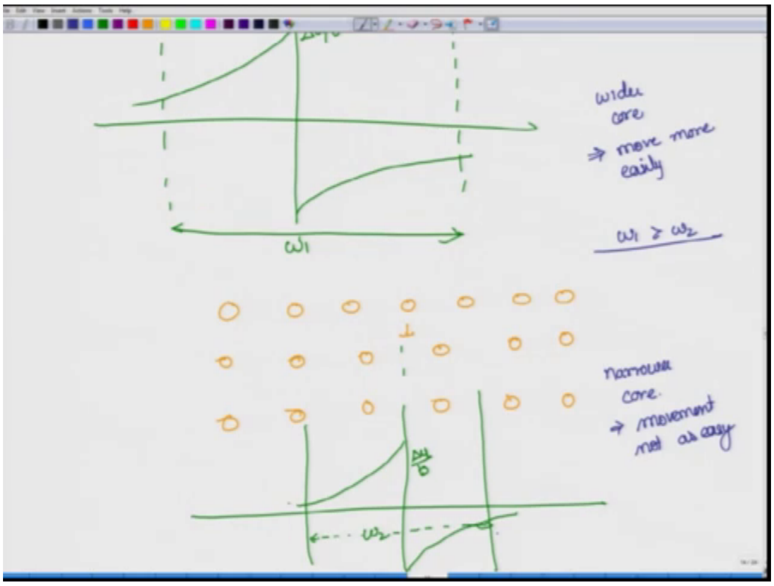

So, again, what where do we have the dislocation over here, but you if you see that lines over here they have already a quite the original ship. So, this is there is more strain at these positions and what we have is if you now draw the strain values what you have is something like this. So, this time the strain or 10 percent strain which is, what we are interested which is where the linear elasticity does not hold is limited to a much smaller region.

So, let us call it w 1; let us call this w 2. So, what we see here is that clearly w 1 is greater than w 2. Now, the width of this dislocation is larger the width of this dislocation is smaller and, because of this their movement would be severely different. They will be completely different on how this dislocation most which has a; so, this has a wider core, this has a narrower core. And you make, you would expect that, that one with the smaller core would move easily, but that is not the case the ones, the dislocation which have a wider core ,they are the ones which move more easily. So, they these move more easily movement not as easy.

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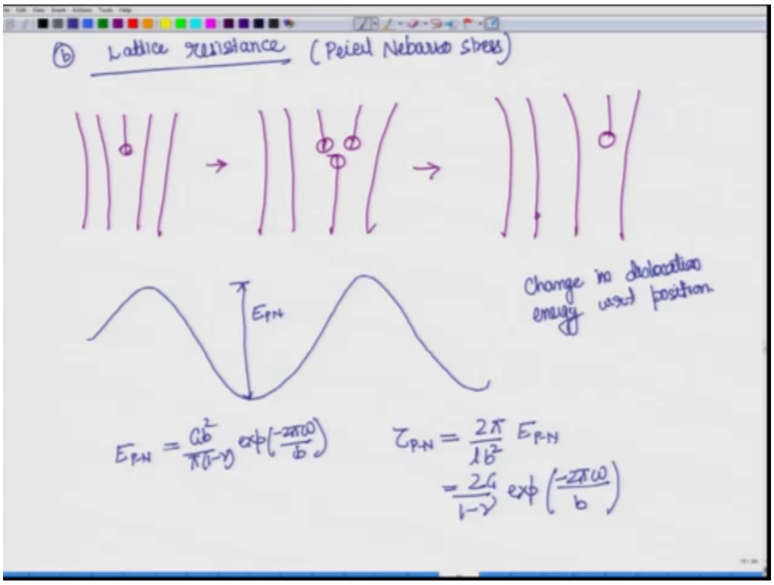

So, this is one aspect of the resistance to dislocation motion. Like the other one, we said is the lattice friction or lattice resistance or this is also called as Peierl Nebarro stress.

So, in this particular case what Peierl and Nebarro found was that the dislocation energy changes with position. Now, if you remember again, if you go back to our, dislocations over here. So, this is the dislocation core if it has to move from this point to this point, this particular layer of atom has to now, shift to the left and this one which is hanging one with this.

This will be get connected this will become the hanging one and therefore, there is a kind of motion that has to take place where from one connected column to another disconnected column or one disconnected column to another disconnected column and this would look more like this.

So, this will have, if you say this is your planes. So, this is the disconnected column at one point, it will be both of these will be disconnected and a there is atom over here. So, now, this is not connected or this is in motion where neither of these are connected. And then finally, since it is moving in which direction finally, what you will have is if. So, there is a transition.

So, earlier this dislocation was between these two planes not this dislocation on the left side, it has three planes on the right side, it has one plane. So, this dislocation has travelled and in travelling it experiences a condition, like this where it will face the largest resistance.

So, there will be energy maxima. Therefore, the total energy of the dislocation is changing the core energy is changing and with respect to position this is what Peierl and Nebarro showed can be seen like this. So, this is what this plot is showing is the change in the dislocation energy with respect to position and this has to be cyclic, because it is a same structure repeating again and again.

So, here you can say, this has the lowest energy when it is disconnected at this particular point, it is something like this where it is not connected with any of the atoms. And then again, in this position, where it is again disconnected at or it has moved to another hm, local minima.

So, it is the lower energy position over here and this gap lot this change in energy is represented as E P N and therefore, to since there is a change in the energy of the overall dislocation with respect to positions. So, there will be a stress required in moving the dislocation from here to here and then back to here.

So, minimum these much stress. So, if we, take the derivative of which, which, we they have done they have shown that E P N can be shown something like this and from this they have derived that tau PN which is the stress. So, the stress would also be cyclic like this. So, is the energy is like this.

So, the stress would also be like this which is the derivative of with is. So, that stress would be, highest somewhere in between over here and it will be, lowest when the energy is again, one of these other position where it is that minima.

So, the tau P N would be is derived to be shown as this and this is showing you the maximum energy or the amplitude we have not shown the cost, cost term over here, which would exist. We are just looking at the amplitude component.

So, this is the tau P N or the stress, the minimum stress that must be applied. If the dislocation is to keep moving meaning if your stress is less than less, then it will not be able to cross the hill. And therefore, dislocation will come back to its original position and it will not move on any further and if you are applying a stress which is continuously higher than this. Then the dislocation can keep hopping like this one, one point to another point, another point and so on and therefore, the movement out the dislocations can take place.

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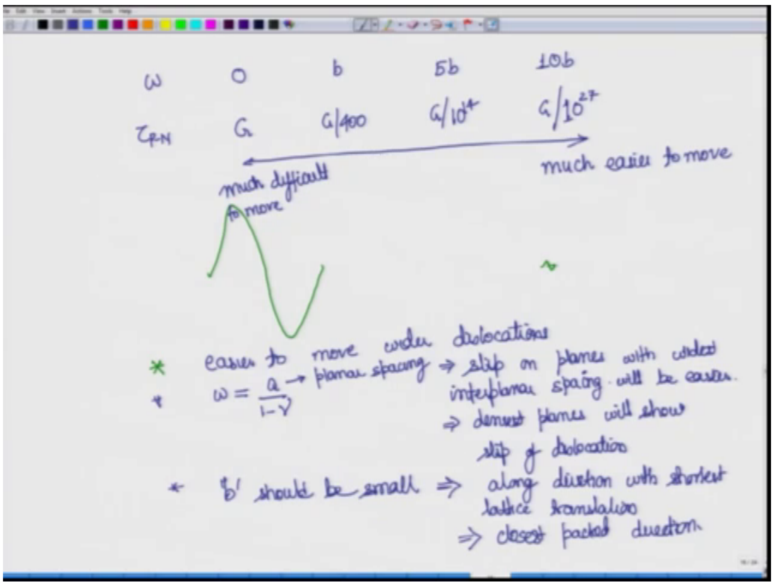

Now, what is the effect of width? We said that width will also make a difference we will see over here. Let us a width tau P N if width is 0 then, you will have to apply a very-very large shear stress. If you increase the width to just 1 b meaning one atom, it already reduces to G by 400; if the width of the dislocation becomes 5 b.

So, what we showed here as two and three lines. Now, we are if you extended it to 5 b, the stress required or the resistance to remove the dislocation reduces by orders of magnitude. So, here it is of the order of 10 to the power 3 and here it becomes G by 10 to the power 14.

So, eleven orders of magnitude smaller stress are required. If your width becomes like this and it goes without saying that when you go to 10 b it will become even smaller.

So, which one will move easier; obviously, this one it will be much easier to move this one, because the peak or the, highest resistance. In this particular case is much smaller. So, much easier to move and this one is much difficult to move. So, the peak is very large here and the peak is very small here. And I cannot even draw the magnitude that we are showing here.

So, peak will be like this over here the peak would be us a very-very, it is no we are comparable to the scale over here, because it is g this is g to by 10 the power 27. So, it is 27 orders of magnitude are smaller. So, this is as small the stress required for the, or the resistance. So, the stress required would be as much smaller that is much easier when you have wider core.

So, that is the effect of geometry of dislocation on motion of the dislocations. So, let us summarize, it is easier to move wider dislocations another aspect which was not mentioned earlier. We had use the term w which can also be written like one your w a by 1 minus nu where a is planar spacing.

Now, this w it is in the exponential factor. Therefore, what we want is that the planar spacing should be largest. If you have, if you go back to the equation over here, you want w to be very large for tau P N to be small and for w to be very large a must be very large. So, this is also giving you information about what particular crystal, in with respect to crystallography which are the planes or directions where dislocations would like to move.

So, what it is implying is that slip on planes with widest inter planar spacing will be easier, because w is equal to a by 1 minus nu which is, where a is the planar spacing and we saw from this equation. That, this is in the exponential minus 2 pi w.

So, that you want w to be larger. So, the tau P N can be smaller and this w will be larger when a is very large which is, which means that planes with the widest inter planar spacing will be easier and when will you have the widest planar spacing when you have the densest planes.

So, this implies densest planes will show slip of dislocation. So, this factor which is in the tau P N is also giving us some information about the geometry. Another aspect that you see over here is b. So, this also gives us some information b is the slip direction.

So, we have talked about slip plane, we saw that slip plane has to be the densest main. Now, b is in the denominator though this has to be very small if it is small. Then it would mean that this quantities, these negative quantities, large and therefore, tau Q N, ghumm again small. So, far b to be small we know that b should be small where is the b smallest this, the b smallest along direction with shortest lattice vector lattice translation.

So, b is small in the shortest where we have the shortest lattice translation or implies where you have the closest packed direction. So, based on this tau P N or when we talk about the resistance to lattice movement.

We saw that, there are two components; one is the core size the large we saw we said earlier that larger core size will move easily. Smaller, core size would move with more difficulty that is one aspect and the second aspect was the lattice resistance where which gives rise to tau P N and the size of the core has direct relation on the tau P N.

Now, we also have the equation derived by Peierl Nebarro what should be the tau P N and from there, we see how the, or the, how the crystallography of the material can we can get more information about the crystallography or the directions of crystal directions of dislocation movement.

With respect to crystallography of the material and what we saw is that a which is the planar inter planar spacing should be very-very, large and for that it means that we have to have densest plane b should be small which means again which it should have the densest direction

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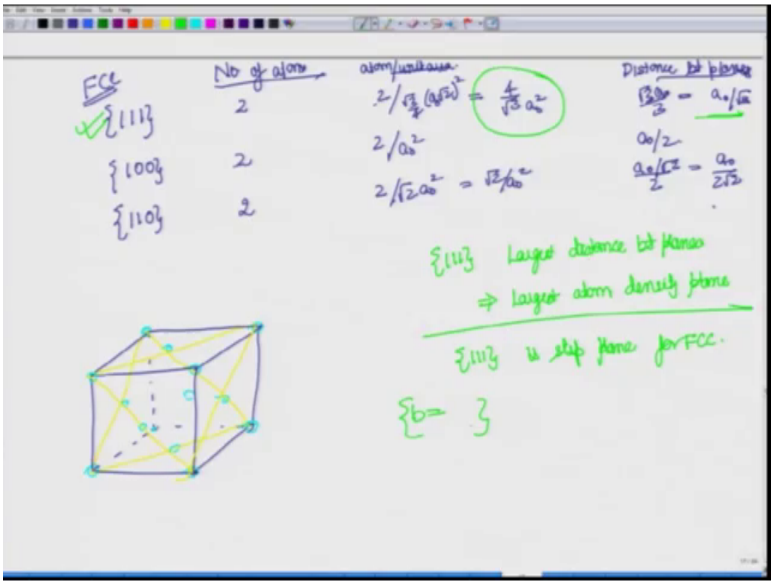

Now, let us now that we have this information, let us try to look what would they would mean for two of the simplest system. One is the FCC and other is the B C C. So, if what we are looking for is the planes with largest inter planar spacing or the densest pack planes and second we are looking at the close packed direction.

So, first let us look at FCC. Let us look at three important planes which are low indices planes where we would expect something to happen. So, let us compare these three different planes if you look at the FCC atom, sorry FCC cell.

So, this is how the FCC atom would this, how FCC cell would look like and here lets what we or looking at 111 plane. So, let me draw the 111 plane. So, this is one of the 11 planes. Similarly, you will have another 1 plane over here.

So, this is one plane this another plane and of course, at this particular location you have, starting of one another plane and this particular location will lead to another starting of the plane. So, in this let us you take about one this particular plane, how many atoms do we have first let us look at the number of atoms.

So, for this particular plane you can see that the number of atoms will be equal to 2. Next, what we want is atoms per unit area, because this is what will give us the densest plane atoms per unit area. So, this is 2 atoms and if you, if this is the, a root 2 and this is the equilateral triangle. Therefore, the area would be root 3 by 4 a root 2 square.

So, this will be 2 divided by root 3 by F4 a root 2 whole square which will come out to 4 by a root 3 a square and since it is lattice parameter. So, will we can write it as a naught. So, this is a naught and similarly at the same time lets calculate what is distance between the planes.

Now, this whole distance from this point to this point is equal to root 3 a root 3 and there are how many planes there are three planes therefore, this, distance between the planes can be written as root 3 a by 3. So, it is again a naught by root 3 for 100 plane. Again, this is very easy to see this is 100 plane how many atoms are there; 2, what is the number of atoms per unit area.

So, the area is a naught square; so, 2 by a naught square and the distance between the planes. So, this is one plane this another plane the distance is equal to a naught by 2 a naught by 2 this is, now let us talk about third plane which is 110.

So, this is the 110 plane again, you can clearly see that there are two atoms here and the area of this is equal to a naught square root 2. So, this becomes 2 by root 2 a naught square equal to root 2 by a naught square and the distance between the planes is equal to from here to here which is equal to a naught by 2 root 2.

So, now, looking at this which one is the largest atom per unit area and we can clearly see that, this is the largest value four by root 3 a naught square. This is the smallest atom per unit area and which is the largest distance between the planes. This is the largest distance between the planes, which is a naught by root 3, because this is the, smallest denominator.

So, this is the largest distance and this one comes out to be the smallest atom per unit area. Therefore, in FCC 111 has the largest distance between planes which implies largest atom density. So, yes again, I take back what i said earlier that this will become the largest atom density. So, four by root 3 is greater than 2 is greater than root 2. So, this is the largest atom density plane. And therefore, 111 is the slip plane for FCC.

So, what we have calculated here is number of atoms, from that we have calculated atom per unit area and from, and we have also independently calculated distance between the planes, what we find is the distance between the planes for 111 is largest meaning they are at the farthest distance apart if the farthest distance apart since the total atomic density, has to be inside the cell has to be constant.

Therefore, the atom density in this particular plane has to be largest which is what we see 4 by root 3 is the largest value is greater than two is greater than root two. So, this has the largest atom density. So, this is the densest or, is it is the densest plane and therefore, 111 is the plane on to which slip will take place and for FCC this happens to be this.

So, we our have already established based on the relation for tau P N that 111 will be the slip plane. Similarly if you look at the burger vector you should be able to derive and will come back to this in the next class in the meantime I would hope that you can you can go back and find what will be the burger vector for FCC. We have already described the slip plane. So, I will come back and meet here.